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Impact of climate changes on the diurnal behaviour of some passerines in some selected habitats of central Punjab, Pakistan

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Present paper provides information on the impact of climate changes on diurnal rhythms of the four passerines viz, house sparrow (*Passer domesticus* Linn.), rosy starling (*Pastor roseus* Linn.), tree swallows (*Tachycineta bicolor* Hirun.), and brown shrike (*Lanius cristatus* Linn.) for two years period in the four major agricultural habitats viz. Faisalabad, Sheikhupura, Toba Tek Singh and Khanewal of Central Punjab, Pakistan. Effects of climate catastrophe have been seriously recognized as important inhibitory factors for birds' sustainable existence and conservation. Among the four habitats, present within 120 kilometre radius from Faisalabad district, observations were conducted weekly on active and passive foraging, and the roost exits and returns throughout the day. Weather changes viz. temperature, precipitation and relative humidity were critically recorded. Impacts of temperature were significant and resulted in decline of the active foraging for the four designated birds (β= -2.36, -1.93,-2.15 and -1.64) whereas, precipitation due to its lowered frequency, exerted negative influence on the house sparrow and brown shrike, but was non-significant for rosy starling and tree swallows. Overall, temperature and relative humidity (RH) were the foremost climate factors and largely reduced the foraging and roosting movements of the four passerine birds'. Nonetheless, effects of lowered rainfall for the four habitats throughout this study were non-significant.
Keywords: Climate, ecosystems, vulnerability, birds, Punjab.

INTRODUCTION

Climate changes lately are considered serious threats to various birds (Parmesan and Yohe, 2003; Parmesan, 2006; Ridchuk *et al*., 2019). Continuous human activities for several decades have altered the existing climate which have resulted increase of earth temperature (0.85^{0}C), rise of sea level (0.23m) and the melting of ice-glaciers (IPCC, 2007; 2013). Undeniably, such changes in temperature have also seriously jeopardized the global biodiversity influenced by the environmental stressors (Marzluff*et al*., 2001; Walther *et al*., 2002; Thomas *et al*., 2004; Pereira *et al*., 2010). Environmental fluctuations are highly unpredictable and, therefore, cause undesirable shifts in the faunal populations (IPCC, 2001; Huntley *et al.*, 2006; O'Mahony, 2015).
Several migratory birds seem to have increase their arrival at the suitable roosting sites in winter and also in summer for better foraging, roosting and nesting opportunities (Gienapp *et al*., 2007; Pearce-Higgins *et al*., 2019) to accelerate and adjust their breeding schedules. Accordingly, incidence of decline in their population owes to the occurring climate changes (Moller *et al.*, 2008; Salido *et al*., 2012). Bird roosting worldwide enables large self-sacrifice to expand the competition for the existing resources (Suzuki and Akiyama, 2008; Conklin and Colwell, 2008). Apparently, adaptive values and fitness for majority of birds depend largely on intra-specific competition (Marzluff *et al*., 1996; Wright *et al*., 2003) and that of the predatory impacts (Rabenold, 1987; Krause and Ruxton, 2002; Rogers *et al*., 2006).
Climate is, therefore, considered as the major driver to alter behavioral performance among birds leading to changes in phenology, roost characteristics and the both intrinsic and extrinsic factors. Thus, there occurs direct effect on their physiological adaptations (Crick, 2004). Weather fluctuations are largely unpredictable and cause undesirable changes to the shifts in the bird populations (Huntley *et al*., 2006; O'Mahony, 2015). Therefore, such variations are assumed to be serious threats to biodiversity of birds and other animals (Gilliland, 2019). Anthropogenic factors and ecosystems vulnerabilities have also reported on serious changes in the decline of useful animal populations (Root *et al*., 2003; Menzel, 2006; Valladares *et al*., 2007; Ockendon *et al*., 2014). According to (Reif and Vermouzek, 2019), several farmland birds have also suffered mortalities in wake of weather

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variations and not only the deforestation was major ecological predicament to deprive them of food and roosting, but direct effects of high temperature, precipitation and habitat fragmentation are also destructive (Szabo *et al*., 2012; Bellard *et al*., 2012; Birdlife international, 2015; Amano, 2020).

Bird movements are inhibited (Moller and Fiddler, 2010) for their space and time orientation (Robinson *et al*., 2010). Whereas, predictable effects can be recorded on the seasonal movements for their consecutive and non-consecutive migratory shifts (Bauer and Hoye, 2014), unpredictable schedules occur owing to the weather changes. The behaviour of house sparrow (*Passer domesticus*) in the rural and urban habitations was largely considered communal in nature; however, lately climate modifications caused non-consecutive shifts to (82%) in the city avenues, and only (18%) in the rural habitats, with (15%) global decline in its existing population (Robinson *et al*., 2005; Birdlife International, 2004; Eaton *et al*., 2008). According to (Shaw *et al*., 2008) some risk in ecological conditions and also due to weather fluctuations the sparrows have not only been deprived of their sustainable roosts but severely impacted foraging periodicities in Europe (Chamberlain *et al*., 2007; Brichetti *et al*., 2008; Murgui, 2009).

The rosy starling (*Pastor roseus*), mainly regarded migratory bird of Europe, seems fairly well adapted in the Asian continent finding suitable ecological conditions and serving as bio-indicator of climate change having widespread population (Ali, 2018). The starling has indicated better ecological adaptations and fitness in varied environments (Clarke *et al*., 1993; Yoder *et al*., 2004) for its territorial roosting. Some individual bird fitness can occur in certain environments based on its instinct and sensitivity to combat climate fluctuations (Minderman *et al*., 2010). Recent impacts of high temperatures, precipitation and that of relative humidity have strongly affected the starling also and caused shifts in its behaviour profiles (Ali *et al*., 1987; Roberts, 1991; Fiedler, 2003; Dunn, 2004; Firrgens *et al*., 2013).Several birds seem to respond I three possible mechanisms; a. to track the ongoing climatic changes and disperse in different geographical zones for finding suitable weather conditions, b. to indicate some adaptations to the prevalent ecological conditions, and c. to feel unfit in the environment to either extinct or perish(Quintero and Weins, 2013). Thus, majority of the avi-fauna presently is stressed by either increase of temperature and also of the other correlated factors leading to their population decline (McCarty, 2001; Mc Laughlin *et al*., 2002; Hansen *et al*., 2006). Perhaps, some birds possess the ability to adjust themselves accordingly to the continued climate changes and with the decreased costs and benefits (Vickers *et al*., 2011). The region of Central Punjab is considered as main agricultural landscape of Pakistan. As such, it contributes (30%) of the overall agricultural requirements (Ahmad *et al*., 2013; Agriculture Pakistan, 2015). The gross domestic products (GDP) of Pakistan largely contribute to agriculture with (42%) income resources provided to the rural habitats and local farmers (GOP, 2019). Therefore, the agriculture remains complex and based on improved technologies to furnish better incentives to the farmers (Iftikhar *et al*., 2019). Occurrence of the canal irrigation system (CIS) is highly well developed throughout Asia which came of age in (1947). Three main irrigation canals viz. Jhang, Gogera and rakh are inter-linked with various water tributaries to water the multiple cropping systems (MCS). Predominantly, the sufficiently large canal-rest houses (CRHs) comprise 12.5 hectares and were established by the British before the partition of Indo-Pak sub-continent to facilitate farmers. Nonetheless, variety of cultivation offered suitable foraging to the vertebrate pests here, which over the years increased gradually and, this, acquired the status of noxious pests (Taber *et al*., 1967). Objectives of this study were, therefore, concerned with assessing three climate variables viz. temperature, precipitation and relative humidity to influence the behaviour profiles of the four passerine birds' in the four major habitats of Central Punjab, Pakistan.

MATERIALS AND METHODS

Present observations regarding assessment of climate changes on four passerine birds' house sparrow (*Passer domesticus* Linn.), rosy starling (*Pastor roseus* Linn.), tree swallows (*Tachycineta bicolor* Hir.) and brown shrike (*Lanius cristatus* Linn.) were extended for two years viz. October, 2017 till September, 2019 in the four major habitats of Central Punjab (Pakistan) viz. Faisalabad, Toba Tek Singh, Sheikhupura and Khanewal.

Study sites: Climate of Faisalabad (31.45^0 N and 73.13^0 E) remains dry hot to humid hot in summer, while cold winters and moderate during spring and fall seasons (Khattak and Khalil, 2015).

Experimental birds**:** A total of four passerine birds' viz. house sparrow (*Passer domesticus*) rosy starling (*Pastor roseus*) tree swallow (*Tachycineta bicolor*) and brown shrike (*Lanius cristatus*) were consecutively observed to ascertain their behavior profiles as influenced by climate variations in the four Central Punjab districts, Faisalabad, Toba Tek Singh and Khanewal located in 120 km radius from Faisalabad.

Methods**:** Studies were conducted for two years (October 2017 through September, 2019) in all the four districts. All the habitats were well vegetated and predominant seasonal cops were present. Observations on weather modalities viz. temperature, precipitation and relative humidity were recorded in all the designated sites of the four districts of Central Punjab. Weekly observations were recorded regarding the day-long active and passive foraging and the roost exits and returns in morning and evening durations. Apparently, of the four birds', non-consecutive (short) and consecutive (long) bird shifts were evident from their original roosts.

***Bird counts*:** Numbers of the four passerine birds were critically assessed and numerically counted as impacted. Observations were compared relative to the three climate variables throughout the day with 30 minutes intervals. Such time durations were constant throughout the studies for maintenance of time-scale uniformity for the bird counts throughout the days. Use of digital weather station (WS-2320 CE-MISOL), was incorporated in all observations to determine the variabilities for temperature, precipitations and relative humidity.

***Statistical analysis*:** The collated data of present study was statistically analyzed using the design Generalized Linear Mixed Model (GLMM).

RESULTS

***Active foraging*:** Foraging is regarded important to the bird existence. It was evident that, influence of temperature, precipitation and relative humidity on the dynamic foraging of the four passerines remained robust (P=0.002**, 0.0015**, 0.004**and0.0017**) respectively whereas, low incidence of rainfall was nearly non-significant. Nonetheless, effects of relative humidity (Rh) were significant to the house sparrow and also to rosy starling. However, their impacts were negligible for the brown shrike and tree swallows (Table 1). Application of the GLMM model, therefore, apparently indicated that with the single degree increase in temperature (ºC),there was decline in foraging for 2.36 *P. domesticus*, 1.93 *P. roseus*, 2.15 *T. bicolor* and 1.64 *L. cristatus*(Figures 1, 2, 3).

***Passive foraging*:** Passive foraging (PF) as depicted by the GLMM indicated that of the three main climate drivers, temperature did not seem to exert significant effects for all the four passerines in all habitats (P=0.069; 0.084; 0.0.69; 0.07), and similarly, impact of little rainfall also remained negligible. Effects of relative humidity (Rh) were also non-significant and evinced that, passive foraging profiles which had occurred due to strong effects of temperature lately, invariably were non-consequential for the four birds (Figures 4, 5, 6).

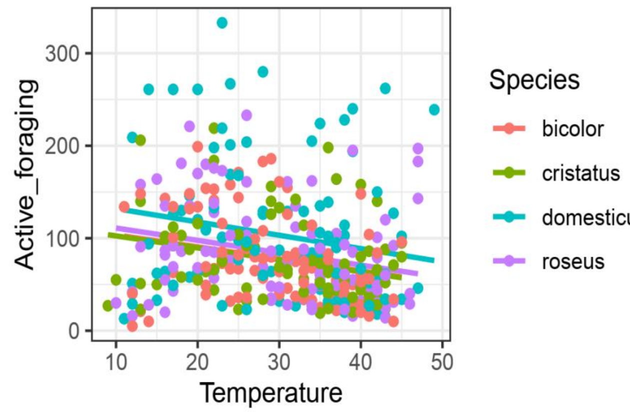

Figure 1. **Impact of temperature on foraging of four bird species.**

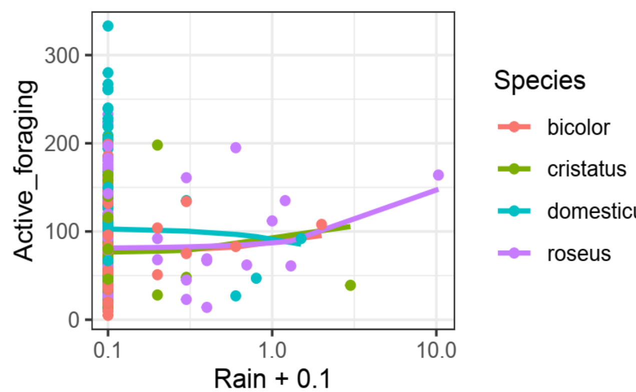

Figure 2. **Impact of rainfall as indicated on bird foraging activities.**

Table 1. **Effects of temperature (ºC), relative humidity (%), and precipitation (mm) recorded on active foraging, of four bird species**.

Bird behaviour	Climate factors	Bird species	Slope (β)	Standard error	t-value	p-value
Active foraging	Temperature	*P. domesticus*	-2.36	±0.76	-3.09	0.002**
		P. roseus	-1.93	±0.59	-3.28	0.001**
		T. bicolor	-2.15	±0.61	-3.51	0.004**
		L. cristatus	-1.64	± 0.50	-3.25	0.002**
	Precipitation	*P. domesticus*	-7.41	±42.2	-0.17	0.860
		P. roseus	7.43	±5.14	1.45	0.150
		T. bicolor	14.4	±22.40	0.64	0.520
		L. cristatus	-1.14	±14.28	-0.08	0.940
	Humidity	*P. domesticus*	-1.35	±0.57	-2.35	0.020*
		P. roseus	-0.92	±0.41	-2.23	0.028*
		T. bicolor	-0.38	± 0.39	-0.98	0.320
		L. cristatus	-0.59	± 0.43	-1.37	0.170

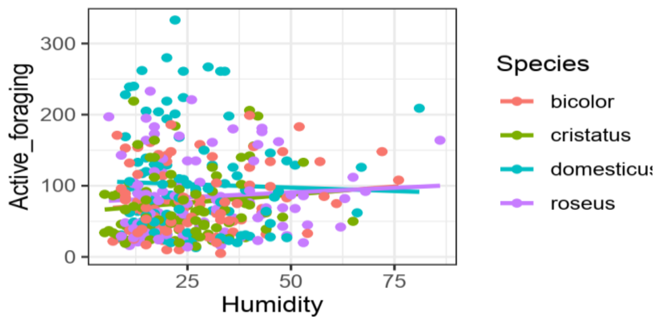

Figure 3. Effects of relative humidity (RH) on active foraging.

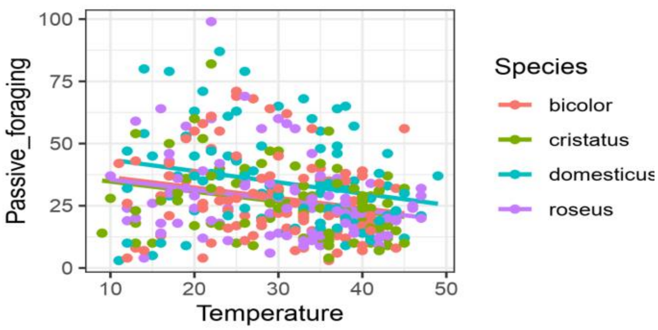

Figure 4. Effect of temperature on passive foraging.

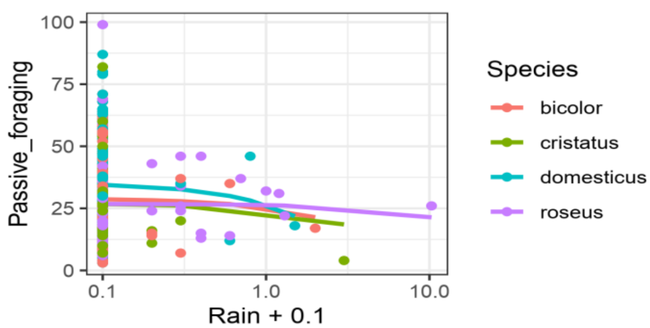

Figure 5. Effect of rain on passive foraging. Precipitation has no significant role in the passive foraging of all four bird species.

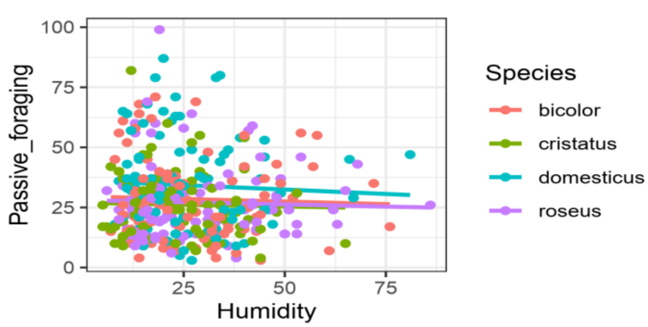

Figure 6. Impacts of humidity on passive foraging. Humidity shows a significant role in passive foraging on three species out of four, except *P. roseus*.

Roosting exits: Roosting behaviour is trivial to all avi-fauna. Predominantly, roosting birds' elicit direct response to any of the altered roosting profiles. In this study, effects of temperature, precipitation and relative humidity for the four designated birds' showed that, temperature yet again was instrumental for their negative slope indicators (-3.05 for *P. domesticus*; -2.20 for *P. roseus*; -1.96 for *T. bicolor* and -2.14 for *L. cristatus*). Roost exits were largely reduced owing to elevated temperature for all the passerine birds. Thus, according to the GLMM, increase of each degree temperature, reduced their roost leaving percentage as (for the sparrow 3.05; for the rosy starling 2.20; tree swallow 1.96 and similarly for the brown shrike, 2.14). Nonetheless, due to low precipitation percentage, there were least significant results except for that of the rosy starling (+11.56) which appeared to augment its roost leaving in pursuit of the abundant insects after the little rain fall. Invariably, a non-significant biological variation of precipitation regarding the three other birds was due to the low rain fall in the designated habitats. Finally, considering the relative humidity (RH) for the four sampled birds, *Tachycineta bicolor* was strongly impacted (0.99%) exits were estimated contrary to the three other birds (Figures 7, 8, 9).

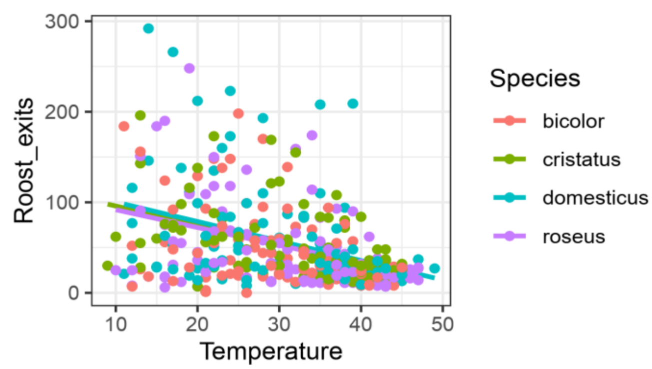

Figure 7. A prominent adverse effect of temperature on Roost exits of almost all four bird species was observed.

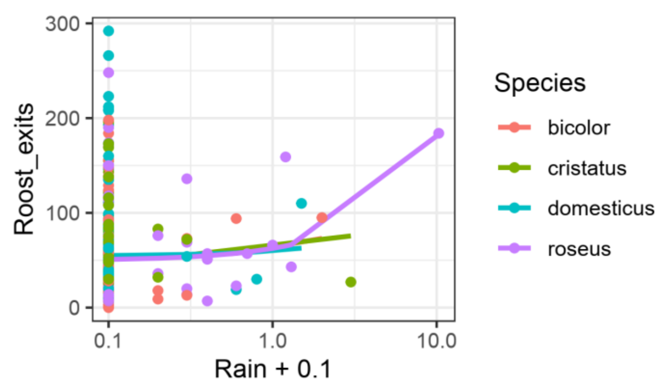

Figure 8. Effect of rain on roost exits indicates strong positive effect on *Pastor roseus*.

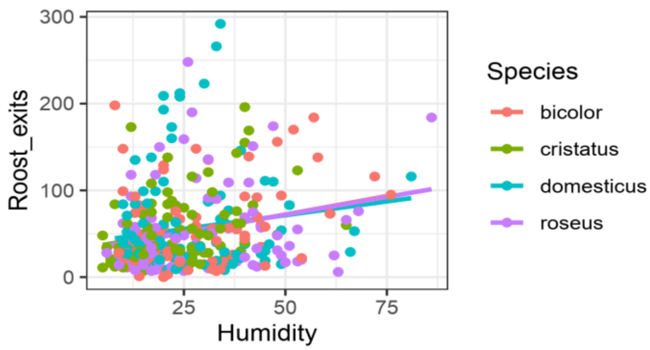

Figure 9. Impact of humidity on the exit of all the four species.

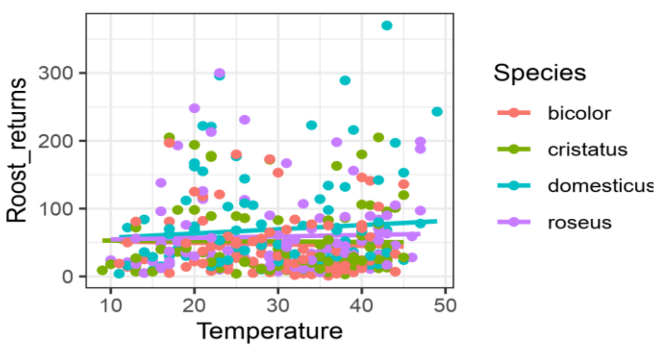

Figure 10. Temperature effects on Roost returns, on the four passerine birds.

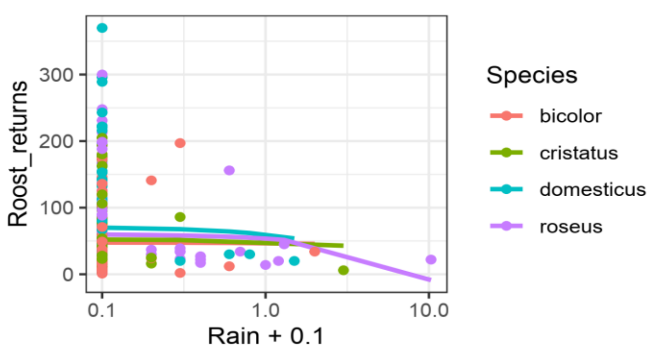

Figure 10. Precipitation impacts on the roost returns of four bird species.

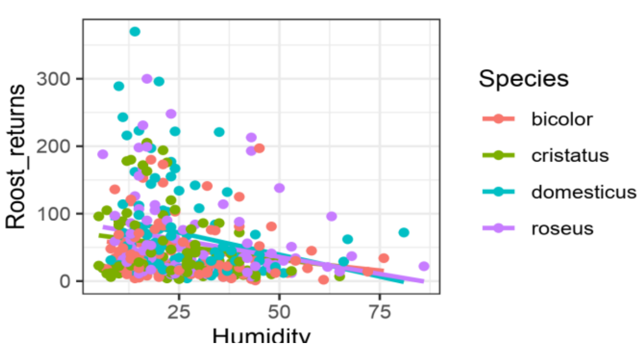

Figure 12. Robust activity of relative humidity in roosting returns of all four birds.

***Roost returns*:** It was apparent that the roost returns figured according to the GLMM Model, temperature and precipitation remained negligible to impact the returns and was, therefore, suitable to it. However, some alterations were ascertained in the elevated relative humidity slope (1.37) for *T. bicolor* and (2.06) for *L. cristatus* (Figures 10, 11, 12).

DISCUSSION

Present study was focused on adjudging the three major weather variables viz. temperature, rainfall and relative humidity regarding behaviour profiles of four passerine birds; *Passer domesticus*, *Pastor roseus*, *Tachycineta bicolor* and *Lanius cristatus*. All of them occur in throughout the cultivations in Central Punjab with their established roosts. Weekly observations were cautiously conducted to indicate impact of each of three climate factors regarding their diurnal foraging and roost behaviour in the four selected habitats.

Foraging and feeding are important aspects of life-history of all birds' on the daily basis. It was differentiated into two types; active and passive. Initially, it was hypothesized that the impacts of climate variables would diminish the foraging periodicities. Apparently, incidence of higher temperature was concerned as the plausible inhibitory factor for their roosting and foraging activities in all four locations as statistically supported by the Generalised Linear Mixed Model (GLMM). Observations on the passive foraging (PF) did not seem to be significant in reduced foraging efficiencies yet were responsible to shift for short and long duration of the four passerine birds as have also reported by (Lourdais *et al*., 2014; Killen *et al*., 2016). Moreover, the micro habitats are considered to be important to dispel certain birds in the increased temperature from their original habitats, and largely drop both the modes of foraging (Brambilla *et al*., 2016; 2017).

Roosting habits, therefore, remain important to the well-being of the avi-fauna. Some of them are regarded logical ecological considerations for the better survival of birds. Majority of the birds adjust to the required environmental changes to facilitate their endurance. Predictable ecological adjustments become unavoidable to them or they suffer extinctions (Baxter and Fairweather, 1998). Roost exits are highly significant in their day-long activities of not only finding suitable food but also to search for tree depressions or cavities to transform as productive nests. It was evident in present study that the roost periodicities (exits and returns) possessed decreased intensity regarding morning and evening hours, and possibly aversion to high temperature was main inhibitory factor to it. Roost movements as have been reported by (Przybylo *et al*., 2000) for flycatchers and some more birds were also of reduced efficiencies owing to the higher temperatures. Lately, warm climate also have impairment on the efficiencies in breeding performance by causing it to occur fairly early and, thus, provoke stress (Inouye *et al*., 2000).

Roost returns were numerically more than their exits in the morning. It was due to the joining of conspecifics to the already returning four passerines to their respective particular communal roosts. Present findings also reported that the GLMM also provided measure of the occurrence of biological variation among the four passerines with their deviated magnitudes from their existence as also shown by (Seavy *et al*., 2005).

Impact of precipitation remained nearly negligible throughout the present observations due to moderate rainfall, where as effect of relative humidity (RH) on the foraging of the four sampled birds had negative influence, and as such, house sparrow and the rosy starling suffered serious decline in their foraging efficiencies. Nevertheless, except for the brown shrike showing more reduced activities, rest of three species expressed negligible impacts. The roost exits further depicted somewhat mixed proportions of the relative humidity and the slow exits of the *P. domesticus* and *P. roseus* and *L. cristatus*. Contrary, significant exits were recorded for the *T. bicolor*. Concurrently, as predicted with the GLMM, relative humidity exerted important impact to inhibit the returns of the four passerines in their specific roosts in the evening (Table.1; Figures.1-12). Similar studies by (Okpara *et al*., 2016) regarding effect of relative humidity on hens in a humid tropical climate also support the present work.

Conclusions: Four passerines are fairly common throughout Central Punjab, but house sparrow with flexible adaptations seemed numerically better. Evidently, all birds' possessed well-established communal roosts for multiple years considering their safety among the old and tall trees. Although weather fluctuations have their impacts on the varied behaviour of birds; it was evinced that temperature was the main driving factor to inhibit efficient foraging activities, while paucity of precipitation could not be regarded to be significant to alter foraging and roosting habits, and relative humidity levied mixed effects on the four passerines in all the habitats. Optimum temperature regarding the active foraging was 25-30°C and for passive foraging below 25°C. Roost exits ranged between 15-20°C and it was 45-50°C for the roost returns. At 25-45% relative humidity, roost exits and active foraging were highest for all the four birds.

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